APPENDIX

I. Blasting Related Accident Abstracts

   a. Injury/Fatality Cases
   b. Flyrock Incidents

II. Associated Articles

III. Example Record Forms

IV. Suggested Blasting Equipment Lists

V. Safety Talk Outlines/Summaries

VI. Flyrock Prevention Communication Memorandum, November 29, 2006

VII. Flyrock Hazard Alert, November 2006

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Abstract of Blasting Accident at XYZ Corp.

On January 19, 1993 a utility worker, at a sandstone quarry, was injured when the front end loader he was operating was struck by material from a blast. The day of the blast the victim was hauling sand from the face to the pump monitor. The blasting contractor was new to the mine, and had come on site to load, and initiate their first blast at the site. The plant manager had shown the contractor the drilled shot, and later that morning the plant manager, and safety supervisor went to the blast site to check on the progress of the loading. The blasting contractor gave the safety supervisor a two-way radio for coordinating the blast when they were ready. At approximately 10:20 a.m. the blaster called the safety supervisor, and told him they were ready to shoot. The safety supervisor followed his normal routine of telling the purchasing agent to begin notifying the neighbors of the blast, and then left to go and set up the seismograph. The safety supervisor, and a contractor employee, both set up their seismographs, called the blaster on the radio, and told him to go ahead and detonate the blast. After one aborted attempt, the blaster detonated the blast. Two quarry workers had not been removed from the blast area, and were in the pit when the blast went off. The blaster had failed to clear the blast area before initiating the shot. The safety supervisor had assumed that the blast area was cleared, but had not asked the blaster to make sure.

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Premature Detonation of Explosives Accident

On February 14, 1994 a premature detonation of explosives occurred at an open pit rock quarry. The blaster had completed loading the previously drilled shot, including making up the surface connections of the non-electric detonating system in use by the operator. The mine routine was to utilize an electric cap to initiate the non-electric system; therefore, the blaster went ahead and hooked the electric cap to the non-electric system. The blaster then hooked the firing line to the electric cap, and pulled the line back to the blasting shelter. After checking for continuity with a Blaster's ohmmeter the blaster then connected the firing line to the blasting machine, and pushed the button to charge the condenser. The blaster noted that the blasting machine indicated that it was ready to fire, and at that point the blaster heard someone coming toward him in a pickup truck. The blast then allegedly fired without the fire button being pushed. The blaster had failed to clear the blast area of personnel prior to connecting the shot to the initiating system. Two truck drivers, and the mine foreman were in the blast area, but fortunately were uninjured as a result of the premature detonation of the shot. The investigation found that the training of the blaster was deficient, which contributed to the accident.

Blast Fatality Abstract #1

On May 23, 1994 a laborer/crane operator was fatally injured when he was struck by flying material generated from a blast. The victim had assisted in the loading, and stemming, of the shot in the multiple bench limestone quarry. The one row of 41 holes in the shot were 12 feet deep, had 3 feet of stemming, and were covered with a woven mat. The victim, and the blaster were standing on the bench above the loaded blast, and were located approximately 120' behind the shot. When the blast was detonated, a piece of flyrock struck the victim in the back. He was taken to the hospital, and died later that day as a result of the injuries. Neither the victim, nor the blaster took shelter prior to detonation of the blast. Their distance from the blast was insufficient to protect them from flying materials generated by the blast.

Blast Fatality Abstract #2

On May 8, 1996 a truck driver/laborer, employed by a blasting contractor, was killed by a premature detonation of an explosive primer. The victim had reported to work at the open pit quarry at his regular time, and had begun to assist fellow contract blasting employees with loading a blast. The victim proceeded to the rear of the blasting truck to make up some additional primers. The primers being used consisted of a nonelectric detonator inserted into the cap well of a cast booster. At approximately 9:20 am the other members of the crew heard, and saw, an explosion at the rear of the blasting truck. They ran to the truck to find the victim dead of massive injuries to his abdomen and torso. A hole blown in the truck's bumper indicated that the victim had been making up a primer on the bumper at the time of the explosion. Two coworkers stated that they had witnessed the victim on two previous occasions using a knife to tap a detonator into a primer, and had warned him against the practice. A wood handled knife, found on the ground about 10' from the victim, caused investigators to suspect that the victim may have been trying to force the detonator into the cast booster.

Premature Blast Accident Abstract

On January 2, 1987, a blasting primer exploded while drill holes were being loaded in preparation for a shot, seriously injuring the certified blaster.

An investigation of the accident by the Virginia Division of Mineral Mining revealed the following:

- The certified blaster, with the assistance of the driller, was loading an 8 hole shot. Apparently, as a primer was being lowered into the 7th hole, it came loose, dropped down the hole and exploded.

- The holes were 3 1/2" in diameter and 30' to 60' deep. 8 holes were drilled in a row on a 35-degree angle, 6' apart. 3" X 16" Tovex, ANFO, and a Detaline firing system was being used.

- Primers were being made up one at a time, with each hole being loaded and stemmed prior to moving to another hole. The caps were being placed on the Detaline by running it through the eyes on the top of the cap (as recommended by the manufacturer). The Detaline booster was placed around the cap and inserted into the package of Tovex and a half hitch was used to secure the package to the Detaline.

- 6 holes had been loaded and the driller was lowering the primer down the 7th drill hole when the line went slack approximately 25' down. (The driller stated that packages of Tovex had come loose several times in the past and the cap had remained on the line, and they had placed it in another package of Tovex and continued without problems). So, the driller turned to pick up another package of Tovex, and then he heard the explosion. He looked around and saw the certified blaster on the ground, with his hands covering his eyes. (The injured blaster received multiple burns and trauma to his eyes and face; he had been virtually over the hole with the angle of the drill hole. The injured blaster was released from the hospital on 1/4/87, but continued to have sight problems in his left eye).

- Questions were raised regarding the practice of placing the primer in the bottom of the hole…and it was stated that that sometimes they did this, and sometimes they put some explosives down first, depending on the condition of the hole and the amount of explosives to be used. The driller stated that in this case the hole was clear and the primer did not hang on anything going down. The piece of Detaline used in the hole was checked and it appeared to have been cut about ¾ away around and torn the rest of the way.

- Conclusions

  The Detaline is believed to have been damaged or cut prior to being placed in the hole or possibly cut when it was passed through the eyes on top of the cap. Subsequently, the line did not support the weight of the package of Tovex and the cap fired and initiated the blast when it dropped approximately 35’ and hit the bottom of drill hole. No Violations of Virginia Mining Laws or Regulations was indicated.

It was recommended that some explosives should be placed in holes before the primers to act as a cushion in case the primer is dropped; and also that no whole or heavy packages of explosives are dropped directly on top of the primers.

It was recommended that a portable reel stand made of non-sparking material should be used to keep the Detaline off the ground and prevent damage.

It was also recommended that tape be used to seal the cap in the packages of explosives and to secure the line to the package (to relieve tension where the line passes through the eyes on the cap).

It was recommended that no person stands over or looks down the drill hole when explosives are being loaded.

FLYROCK ABSTRACT
CASE #1

In 1991 a granite quarry (located in Virginia) set off a shot that generated flyrock causing serious/major damage to two (2) homes, a garage, boat, basketball goal, along with other miscellaneous damage. The damaged neighborhood was approximately 2000’ (ft) distance from the shot location and people were close-by. A rock weighing approximately 17 lbs. and measuring 6” x 71/2” x 41/2” had gone through the wall of one house doing considerable damage to the wall and furniture inside. The second residence/home had a rock go through the outer brick wall and lodge in the inside wall. The picture window was broken, there was inside wall damage, and a bookcase sitting against the wall was damaged with litter around the room from the bookcase. Another rock had gone through the garage and exited through the opposite end of the building doing considerable damage.

The shot was designed using a laser transit. The shot pattern was 13’ x 16’ with bore holes at a depth of 44’, 3’ of sub-drilling, 8’ of stemming, 33 holes, 2 rows, with the front rows drilled at an angle. 12,887 pounds of explosives was used with a powder factor of 1.94.

A closure order was issued by the state mine inspector stopping all blasting until the investigation was complete and a new blasting plan submitted and approved by the Division of Mineral Mining.

It was of the opinion of those investigating the mishap that there was a weakness in the burden between the face and shot holes.

SEE THE FOLLOWING PAGE FOR NEWS ARTICLE AND LAYOUT

Rock Shower

Quarry blast sends rocks flying

AP photo

[redacted] looks through hole in outside wall of his home that was caused by flying rocks.

[redacted] (AP) — Several houses were damaged in a rock shower caused by a blast at a nearby stone quarry, residents of a [redacted] neighborhood said.

Officials from the state Department of Mines, Minerals and Energy were investigating the incident Wednesday, said Bill Roller, director of the Division of Mineral Mining.

Roller said [redacted], [redacted] has been ordered to suspend blasting until the investigation is complete.

[redacted] said he was standing on his carport Tuesday afternoon when he heard an explosion, looked up and saw "small boulders" flying toward his house. One of the rocks destroyed a basketball goal, then smashed through the brick wall of his home about six feet from where he was standing.

The rock left a foot-wide hole visible from the outside of the house. Inside, where the rock emerged from the wall in the living room, a hole almost six feet in diameter could be seen behind a broken bookshelf. The floor was littered with books, broken ceramic and porcelain knick-knacks and trophies won by the [redacted] children.

Two other rocks knocked holes in Doss' garage roof and wall.

[redacted] area manager [redacted] said the firm is conducting its own investigation. [redacted] company doing the blasting, also was investigating, [redacted] said.

FLYROCK ABSTRACT
CASE #2

On November 3, 1989 a limestone quarry located in Virginia set off a shot that generated flyrock and excessive airblast. Twenty three (23) homes were damaged. Three (3) homes had structural damage from flyrock and twenty (2) homes had glass broken from their windows.

After inspecting the highwall, muckpile, and talking to the contract driller, it was determined that as many as five (5) holes may have fired at the same time (the blast was timed/designed for one hole to fire at a time. Cracks in the wall on one end and the driller having trouble with air coming out of several holes when he was drilling an individual hole leads one to believe that several holes were initiated at one time.

The shot was bulk loaded and cracks between the holes could have been filled with explosives. The weakness/cavities in the geological structure of the formation/rock to be shot and the failure to recognize this potential lead to this incident occurring.

The airblast for this shot was in excess of 145 decibels. Two (2) closure orders and one (1) notice of violation were issued to the mine operator. This regulatory action stopped all blasting at this quarry until a new blasting plan could be submitted and approved by the Division of Mineral Mining.

SAFETY TALK

Drilling and Blasting Safety

by Robert E. Morgan

The extraction of rock and other consolidated minerals produced by the mineral mining industry usually requires the use of drilling equipment and explosives. Federal and state regulations address the safe use of various types of drills and explosive materials.

Drilling Equipment

The mine operator or independent drilling contractor must provide drillers with equipment maintained in accordance with the manufacturer's specifications and in safe operating condition. Typically this translates into pneumatic/hydraulic pressure controls, guards on moving parts, wet or dry dust control devices, and braking/steering systems for the truck or track carrier. In addition, drill steel racks and operator platforms or cabs must be maintained to protect the drill operator.

The equipment operator must conduct a pre-shift inspection of the drill prior to use each shift. This requires the person to be trained in both operations and light maintenance procedures. Any safety defect found during the pre-shift inspection must be corrected prior to use of the drill. Before starting work, the driller and helper must have appropriate personal protection equipment (PPE) such as safety glasses, safety boots, and hard hat. It is also important to remove finger rings, and any loose-fitting clothing articles that may get caught on parts on the drill.

Drilling Work Environment

Prior to starting work at the quarry bench, drillers must inspect their assigned work environment for potential safety hazards. The area must also be checked by the certified foreman. The inspection should focus on the drill bench, the free-face, and the wall or bench above or behind. Hazards such as fractures (back-break) near the edge of the bench, over-hanging rocks, or geologic conditions that create an unstable work area must be eliminated prior to the start of work. When drilling the first row of boreholes, it is important to stay a safe distance from the edge of the bench. A safety harness and lifeline may be required when measuring the free-face where back-break fractures are present. Health hazards related to silica dust and noise can be minimized by use of dust control devices and hearing protection that must be provided. Drillers should be constantly on the alert for hazards that may develop in their work environment as a result of drilling or other unrelated activities.

Communication with Blasters

The pattern of a drilled shot and the geologic characteristics of each borehole are important elements which must be taken into consideration by the certified blaster when designing the blast. The transmittal of clear and accurate drilling data to the blaster is essential for safe blasting. This can best be achieved by drillers using drill logbooks which detail general and specific borehole information to the blaster. This information allows the blaster to load the minimum amount of explosives necessary for the desired fragmentation while reducing risks (flyrock/airblast/vibration damage) and lowering production costs.

Blast Area Security

Prior to the start of loading a blast, all persons and equipment, except the loading crew, must be removed from the drill bench and free-face area (blast site). This procedure is necessary to protect other persons from the effects of a premature detonation accident. In addition, access to the drill bench and the area in front of (180 degrees) the free-face must be barricaded or guarded to prevent other persons from entering.

Once the blast is completely loaded and ready for detonation, the entire pit area (blast area) must be cleared of persons who could be injured by the effects of the blast. Blast warning signals must be established and posted to warn miners, contractors, and other persons of the ensuing blast so they can go to a designated safe area until the "all clear" signal is given. Detonation must not occur until the blaster and mine officials are assured that the blast area is clear. This may require posting guards at both mine and public roads.

Safe Storage of Explosive Materials

Federal and state regulations require explosive materials such as detonators, high explosives, and blasting agents be stored in magazines approved by the Institute of Manufacturers of Explosives (IME). Construction of such magazines can range from over-the-road drop trailers for blasting agents, to steel-covered wood or masonry magazines for detonators and high explosives. Magazines must be located in a secure area, kept locked, and inspected regularly, Any theft or unaccounted loss of inventory must be reported to state authorities and the ATF.

Transportation of Explosives on Mine Property

Vehicles used to transport explosive materials on mine property must be in safe operating condition and posted with explosives warning placards. If detonators and explosives are transported together, they must be separated by 4" of hardwood or the IME equivalent. The vehicle should not be taken to the blast site until the area is cleared of other persons and equipment. The loaded vehicle must be operated in a safe manner and not left unattended at any time. When distributing explosive materials from the vehicle, care must be taken to avoid running over loaded boreholes or explosive materials on the ground.

Safe Use of Explosives

Persons who do blasting at mineral mines must be certified in many states. The certified blaster must be in direct charge of blasting activities, and is responsible for designing blasts which produce the desired fragmentation with the least potential for flyrock or other dangerous effects. The following requirements are important to ensure safe blasting:

- Persons who assist the blaster must be trained in the materials and methods being used.
- Blast site must be cleared prior to start of loading.
- Blast area beyond the blast site must be cleared prior detonation.
- Blast site must be free of safety hazards.
- Boreholes must be cleared of obstructions prior to start of loading.
- Weather conditions must not pose a hazard to loading crew.
- Detonators and high explosives must be kept separated until they are ready to be placed in borehole.
- Smoking is prohibited within 50 feet of loading area.
- Blaster must design blast to comply with limits for ground vibration and airblast.

A careful analysis of geologic conditions of material to be blasted and the implementation of the above safeguards will ensure the safety of persons at the mine, and minimize impact of blasting on neighbors.

Blasting Restrictions - Airblast and Ground Vibration

State regulations often establish limits for airblast and ground vibration measured at inhabited buildings not owned or leased by the mine operator. Ground vibration limits are based upon the method of compliance chosen by the mine operator. There are three methods to choose from:

1) Mine operator measures airblast and ground vibration by use of seismograph for each blast to assure airblast does not exceed 129 decibels and that ground vibration (peak particle velocity) does not exceed 1.00 inches per second (ips) at a distance of 301-5000 feet from blast site; or 1.25 ips at 300 feet, and .75 ips at more than 5,000.

2) Mine operator, who does not have a seismograph, uses the maximum charge weight per delay period method to calculate the maximum pounds of explosives that can be detonated on the same delay cap period. This method requires the certified blaster to take into careful consideration the distance to the nearest neighbor, and the scaled distance factor contained in DMM regulations.

3) The mine operator use an approved alternative blasting limit determined for each blast based upon frequency analysis of ground vibration waves produced by the blast. Using this method can result in limits that may be higher or lower than the usual 1.00 ips.

It is important that the mine operator inform the contract blaster responsible for designing the blast the method of compliance being used, or any other restrictions imposed by local authorities.

Public Relations with Neighbors

Blasting produces ground vibration and airblast which can result in structural response at off-site buildings. This perceived motion can be very disturbing to homeowners. Therefore, it is advantageous to establish good public relations with nearby neighbors. Most homeowners mistakenly believe that any motion of window glass or house structure originates from ground vibration striking the foundation of the house; when in fact the concussion element of airblast is often the culprit. DMM safety & health regulations establish maximum limits for both ground vibration and airblast based on comprehensive studies conducted by the U.S. Bureau of Mines (USBM).

Mine operators often receive blasting complaints from neighbors even though they are well within ground vibration and airblast limits. This can often be attributed to the fact that most homeowners are not knowledgeable about blasting; therefore, their concerns may be alleviated by meeting with them to discuss how blasts are designed to minimize effects, and how structure response from blasting compares with other sources such as closing doors, loud traffic, etc. In addition, mine operators can request technical assistance from their explosives distributor or state regulatory agency to address blasting concerns by neighbors.

As a Virginia state mine inspector, Robert E. Morgan deals with all aspects of explosives, enforcement of state laws and regulations, citizen blasting complaints, investigation of blasting accidents, development of blaster training and certification curriculum, and promulgation of state mining regulations related to explosives and blasting. He has a Bachelor's degree in management of mining sciences, and received his initial training in tactical use of explosives in 1967 at the U.S. Army's Officer Candidate School, Ft. Knox, KY. He is an ISEE member and has made numerous technical presentations at various chapter seminars and conferences.

Blasting continues to be both an art and a science, relying heavily upon good judgement by the blaster in charge

Flyrock— a blaster's worst nightmare

By Robert E. Morgan

Over the years, the mining industry has developed many terms to describe various processes or events associated with the production of minerals.

Of all these terms, however, few can provoke the degree of nightmarish images as does the dreaded term—***flyrock***. The high degree of anguish brought about by the term is justified by the high potential for property damage or personal injury normally associated with uncontrolled flying material generated by a blast.

For the blaster in charge of the blast and and the mine operator who assumes overall responsibility, the mention of the word conjures visions of long, costly confrontations with adjoining property owners and regulatory agencies.

In recent years, the explosives industry has developed many products that improve fragmentation and overall safety. But, a safe and effective product is only one half of the equation. Blasters who use the products must ensure that they are used safely and effectively.

A recent analysis of blasting incidents in Virginia revealed that flyrock often occurred as a result of:

- shallow boreholes used to eliminate toe on the face
- insufficient stemming of boreholes
- inadequate burden around boreholes drilled at an angle

For the Blaster in charge, the mention of flyrock conjures images of confrontations with neighbors and regulatory agencies

Possible causes

Shallow boreholes (snake holes) used to break toe on the face can often be eliminated by increasing the amount of subdrilling in the front line boreholes and loading the bottom portion with a high density explosive product.

The risk of flyrock resulting from insufficient stemming of boreholes can normally be eliminated by ensuring a 1:1 ratio of borehole stemming to burden.

Flyrock resulting from inadequate burden was the culprit in many incidents where rock was thrown in excess of 1,000 ft with subsequent property damage.

In most instances, angled boreholes were used in the front row of the shot. When angled boreholes are used, there is often an increased risk of flyrock from inadequate burden.

Contributors to flyrock

- angled boreholes
- shallow boreholes
- inadequate burden
- insufficient stemming
- overloaded boreholes
- secondary blasting of boulders

The risk can be significantly reduced by changing the direction of face development when mining an inclined stratum. In most cases, better fragmentation and ground control can be achieved by blasting perpendicular to the strike plane of the stratum.

If angled boreholes must be used, burden should be accurately measured by mechanical means (burden pole) or by the

As a representative of Virginia's mine safety/reclamation enforcement agency, Robert E. Morgan enforces state blasting regulations, investigates blasting complaints and teaches explosives safety and blaster certification classes. He also developed the agency's blaster training course and served as chairman of the state's advisory committee on explosives.

newly introduced laser profiling system. Using techniques that minimize the risk of flyrock is only one factor that must be taken into account by the certified blaster.

A successful blast is the culmination of several important factors that must be taken into consideration including:

- **evaluation of the rock strata**
- **design of the drill pattern**
- **design of the detonation sequence**
- **calculation of powder factors**
- **compliance with state and/or federal blasting regulations**
- **sensitivity of adjoining property owners**
- **good judgement by the blaster in charge**

A miscalculation or flawed judgement by the blaster in any of these factors may produce a highly undesirable result—flyrock.

To prevent flyrock or other undesirable effects, operators must ensure that their blasters are competent in all factors relating to both drilling and blasting. This is the reason that Virginia, and some other states, have adopted regulations requiring training and certification of blasters.

Virginia, and other states, have adopted regulations requiring training and certification of blasters

The focus of any blaster's training and certification program must be directed toward designing a blast that produces the desired fragmentation with the least potential for personal injury or property damage.

Unfortunately, we can never totally eliminate the potential for error in any given situation, but the blasters in charge must assure themselves that they have considered all relevant factors and designed the blast to the best of their ability. When this has been accomplished, the chance of error is greatly diminished and overall safety improved.

There is also an obligation for the regulatory agency with the responsibility of investigating accidents involving flyrock or explosives in general. The investigation should focus on the cause of the incident and specify the preventive measures based on sound blasting practices. In most instances, the cause of flyrock will be the design or loading factors used in the particular blast.

And finally, the information relating to the cause of flyrock and preventative measures must be disseminated to other blasters in the mining industry in order to prevent a similar occurrence. The investigation report should serve as a vital educational link in the agency's effort to reduce blasting accidents.

As with most accidents, the nightmare of flyrock can best be avoided by using prevention techniques in all stages of the blast: **planning, drilling, loading** and **detonation**.

Blasting has been, and continues to be, both an art and a science which relies heavily upon good judgement by the blaster in charge. ■

Wild Flyrock

Mine	*Rock*	*Distance*	*Powder Factor*	*Possible Cause*
Conklin quarry	limestone	3,063.6 ft	0.45 lb/yd^3	Overloaded holes (?)
Sibley quarry	limestone	1,159.2 ft	0.9 lb/yd^3	Undetermined
Roberta quarry	limestone	4,057.2 ft	~1.7 lb/yd^3	Undetermined
Falling springs quarry	limestone	5,050.8 ft	0.7 lb/yd^3	Fissures; also marginal stemming
Okalona quarry	limestone	4,057.2 ft	[a]	Overloaded holes
Oglesby quarry	limestone	6,292.8 ft	[a]	Undetermined
Latah quarry	trap rock	828.0 ft	0.68 lb/yd^3	Undetermined[b]
Mine O	taconite	11,360.2 ft	1.2 lb/yd^3	Insufficient stemming
Barkely pit	porphyry	2,119.7 ft	[a]	Some holes may have partially caved in; consequently, explosive load could have risen much higher than planned
Mine A	Sandstone	1,987.2 ft	0.53 lb/yd^3	Fissures

[a] **Insufficient information to complete**
[b] **Flyrock must have originated at bench top since observed flight time is much too long for flyrock vertical face**

Source: Roth, J. (1979), "A Model for the Determination of Flyrock Range as a Function of Shot Conditions," report prepared for the U.S. Bureau of Mines by Management Services Association, Los Altos, California, NTIS, PB81-222358.

Flyrock Resulting from Surface Mine Blasting

by Robert E. Morgan
Division of Mineral Mining (DMM)

The following is a Virginia Department of Mines, Minerals, & Energy technical presentation to the Potomac Chapter, International Society of Explosives Engineers' 12th Annual Conference, October 1, 1999, in Hagerstown, Maryland.

With improved methods for designing and detonating shots, the potential for flyrock can be significantly decreased, but there are few absolutes in blasting. Blasters must learn from the mistakes of others. Blasters must conscientiously employ control measures to minimize the risk of flyrock. The worst case incidents, which tend to be widely reported by the media, should serve as a reminder to us all that minimizing the risk of flyrock must be incorporated into the design of the drill pattern and blast design.

When things go wrong in a shot, the consequence could be poor fragmentation, increased airblast/vibration, or rock thrown beyond the intended limit. If that uncontrolled material generated by the blast impacts and injures a person or private property, an investigation is initiated to determine the cause and contributing factors. Flyrock incident data collected over the years and reported in regulatory reports, trade association publications, and the ISEE Blasters' Handbook include the following conditions or practices:

- *Undetected geologic weakness in rock being blasted*
- *Excessive amount of powder for the actual burden*
- *Inadequate burden for the amount of powder*
- *Increased amount of powder in voids, crevices, mud seams, etc.*
- *Inadequate amount, or ineffective stemming, in borehole*
- *Lift/sinking shot, or over-confined shot without adequate relief*
- *Too much, or not enough, timing between holes*
- *Hole(s) firing out of sequence*

Failure of blasters to adequately address these conditions or practices can pose a risk to miners or private property owners beyond the mine. The "***bottom line***" for blasters is to design the shot in such a way as to avoid too much powder and not enough rock in order to achieve the desired fragmentation with the least potential for flyrock. The following flyrock control measures are just a sample of precautions that can be employed:

- **Adjust blasting direction and drill pattern to be consistent with specific geologic conditions**
- **Accurately measure (unequal) burden on the free face to be drilled and blasted**
- **Design the drill pattern and shot design to provide adequate burden, stemming and timing**
- **Adjust powder factor in areas of free face with variable burden**
- **Design shot in a manner that rock is not thrown beyond confines of quarry pit**

Careful consideration of the geologic condition of rock to be blasted, precise calculation of the minimum amount of powder required to achieve desired fragmentation, and minimizing adverse impact upon adjoining property owners will result in safe and effective blasting.

BLASTING REPORT RECORD

DMM Safety and Health Regulation 4 VAC 25-40-810 requires a detailed record of each blast be prepared by the BMME certified blaster immediately after completion of each shot. The records must be kept at the mine office for 3 years.

COMPANY____**PERMIT #**__________________________

Date__________________ Time________________ Weather__________________________________

Blast Location____ Bench No.__________________
Material Blasted_________No. of Rows___________ Total No. of Boreholes_________________
Borehole Diameter_____inches Depth of Boreholes_____feet Condition of Boreholes____________
Length of Stemming_____feet Type of Stemming________
Burden_____feet Spacing_____feet
Distance (D) & Direction (Ds) to Nearest Inhabited Building (D)_______________ (Ds)_______

Results of Seismic Test

Location_____________________________

Vibration: L _______ in/sec ______ frequency
T ______ in/sec ______ frequency
V ______ in/sec ______ frequency
Airblast: ________ dBs _______ max allowed dBs

Lbs. Explosives Per Borehole____________________ Total Lbs. Explosive Materials Used__________
No. of Holes/Delay Period (8ms)__ Max. Charge Weight Per Delay Period________________lbs.
Method Used to Determine Max. Charge Weight/Delay Period _____W/Ds Formulas
_____ N.A. Seismic Testing

Type & Amount of Explosive Materials Used

Manufacturer & Type of Explosive Material	Pounds of Explosive Material Used

Type Initiation System Used_____________________Manufacturer______________________________

Number of Detonators & Delay Periods Used	Delay Period

Shot Design (delay sequence & timing) and Profile of Front Line Boreholes

On back of this form diagram and specify initiation (timing) sequence, front-line borehole profiles, or any special conditions or precautionary measures used.

______________________________________ ______________________________

SIGNATURE OF CERTIFIED BLASTER IN CHARGE OF BLAST **CERTIFICATION #**

BLASTING REPORT

Blast No. ____________

Name of Plant ____________

Date ____________ Time of Shot ____________

Location of Blast in Quarry ____________

Grid ____________ Grid Map Date ____________ Bench ____________

Weather ____________ Ceiling ____________ Temperature ____________ Wind From ____________

Direction and Distance to Nearest Non-Company Building: Feet ____________ Dir. ____________

Seismograph Location A: ____________

B: ____________

Grid A: ____________ B: ____________

Stationary Seismograph Readings Max. I.P.S. ____________ Frequency ____________ Air ____________

Shot Data

		Explosives		
No. Holes				
Hole Diameter		Type	Size	Pounds
Hole Depth				
Sub-Drilling				
Avg. Stem Face Holes				
Stem Other Holes				
Burden Front Line				
Burden Other Holes				
Spacing Front Line				
Spacing Other Holes				
Tons Per Cubic Yard		Total Explosives Pounds in Shot		

Type of Blasting Caps: Electric ____________ Non Electric ____________

Brand Name ____________

In Hole Caps: Delay ____________ No. Used ____________ Delay ____________ No. Used ____________

Surface Delay: Delay ____________ No. Used ____________ Delay ____________ No. Used ____________

Surface Delay: Delay ____________ No. Used ____________ Delay ____________ No. Used ____________

Total Cost of Blast ____________ Tons in Shot ____________ Cost Per Ton ____________

Percent of Anfo ____________ Percent of Fuel if Bulk Loaded ____________

Avg. Explosives Per Hole ____________ No. Holes Per Delay ____________

Maximum Lbs. Per Delay ____________ Powder Factor ____________

Blaster's Signature ____________ Blaster's No. ____________

Superintendent or Foreman's Signature ____________

BLAST REPORT

						CUSTOMER NO.	SHOT NO.
CUSTOMER NAME				CUSTOMER LOCATION (CITY / STATE)			
BENCH LOCATION				BLASTER		LICENSING STATE	LICENSE NO.
START TIME	END TIME	TOTAL TIME	CREW SIZE	TRUCK NO.	TRUCK NO.	TRUCK NO.	TRUCK NO.
PATTERN OK?	HOLES OK?	FACE OK?	BENCH OK?	FLOOR OK?	SIGNS OK?	SHELTER OK?	SECURITY OK?
SHOT DATE	SHOT DAY	SHOT TIME	WEATHER CONDITIONS		TEMPERATURE	WIND SPEED	WIND DIRECTION
HOLE DIAMETER	NUMBER OF HOLES	NUMBER OF ROWS	BURDEN (FT)	SPACING (FT)	AVG. FACE HEIGHT	SUBDRILLING (FT)	HOLE DEPTH (FT)
DRILLED FEET	1ST ROW STEMMING	AVERAGE STEMMING	ELECTRIC / NONEL?	SEQ. TIMER?	TIMER SETTING	DELAY / HOLE	DELAY / ROW
HOLES / DELAY	TOTAL POUNDS	POUNDS / HOLE	LBS. / DELAY	MATERIAL BLASTED		LBS. / CU.YD.	TONS / LB.
EST. YIELD - CU.YDS.		NUMBER OF HOLES	BURDEN (FT)	SPACING (FT)	FACE HEIGHT (FT)	FACTOR	CUBIC YARDS
						X 0.03704	
EST. YIELD - TONS		NUMBER OF HOLES	BURDEN (FT)	SPACING (FT)	FACE HEIGHT (FT)	FACTOR	TONS
						X 0.0____	
SEISMOGRAPH LOCATION		SEISMOGRAPH OPERATOR		TYPE OF SEISMOGRAPH		SERIAL NUMBER	CALIBRATION DATE
DISTANCE TO BLAST	DIST. TO STRUCTURE	HOW MEASURED?	TRIGGER SETTING	P.P. VELOCITY	FREQUENCY	dB (SOUND)	SCALED DISTANCE
SEISMOGRAPH LOCATION		SEISMOGRAPH OPERATOR		TYPE OF SEISMOGRAPH		SERIAL NUMBER	CALIBRATION DATE
DISTANCE TO BLAST	DIST. TO STRUCTURE	HOW MEASURED?	TRIGGER SETTING	P.P. VELOCITY	FREQUENCY	dB (SOUND)	SCALED DISTANCE
NAME OF FIRM DOING ANALYSIS				SEISMOGRAPH OPERATOR SIGNATURE			

HOLE	PRODUCT	POUNDS
	TOTAL POUNDS	

SHOT DIAGRAM

BLASTER'S SIGNATURE →

DRILL REPORT

CUSTOMER NAME	CUSTOMER LOCATION (CITY / STATE)
BENCH LOCATION	DRILLER

HOLE NUMBER	OVER-BURDEN	SEAMS @ ? DEPTH	MUD @ ? DEPTH	WATER @ ? DEPTH	TOTAL DEPTH	HOLE NUMBER	OVER-BURDEN	SEAMS @ ? DEPTH	MUD @ ? DEPTH	WATER @ ? DEPTH	TOTAL DEPTH
1						26					
2						27					
3						28					
4						29					
5						30					
6						31					
7						32					
8						33					
9						34					
10						35					
11						36					
12						37					
13						38					
14						39					
15						40					
16						41					
17						42					
18						43					
19						44					
20						45					
21						46					
22						47					
23						48					
24						49					
25						50					

DRILLER SIGNATURE

BLASTER SIGNATURE

GENERAL INFORMATION

1. Company Name ____________________________________Permit No. ________________
2. Location of Blast ___________________________________ Date/Time ________________
3. Nearest Protected Structure ____

   Direction and Distance (feet) ______________________
4. Weather Conditions ____
5. Type(s) of material blasted ____
6. Mats or other protection used ____

BLAST INFORMATION

7. Type(s) of explosives used: Powder_________________ Primers ______________
8. Total weight of explosives used: Powder _________+ Primers ___________ = __________ lbs.
9. Blasthole Data: Number ____________ Diameter _____________ Depth _______________

   Burden _____________ Spacing ______________
10. Stemming Data: Type of Material ____
11. Types of Delays Used and Delay Periods ____
12. Maximum Weight of Explosive Allowed per Delay Period (*show approximate formula and answer)*

    ____

    0-300 ft. W=(d/50)2 301-5,000 ft. W=(d/55)2 Over 5,001 ft W= (d/65)2

    ____
13. Maximum Weight of Explosives Used per Delay Period ______________________________
14. Weight of Explosives Used per Hole ____
15. Method of Firing and Type(s) of Circuits ____

    ____

SEISMOGRAPH DATA

16. Data and Time of Recording ____
17. Type of Instrument ____
18. Sensitivity ____
19. Calibration Signal or Certificate of Annual Calibration (attachment)
20. Name of Person Taking Readings ____
21. Location of Seismograph (*including distance from blast)* ______________________________

    ____

22. Vibrations Recorded: Longitudinal: ______________________

Transverse: ______________________

Vertical: ______________________

Air Blast: ______________________

23. Name of Person and Firm Analyzing Readings ______________________

24. **SKETCH OF DELAY PATTERN**

COMMENTS

25. Include any special design features, such as decking. Include reasons and conditions for unscheduled blasts.

____

____

____

____

Name of Blaster-in-Charge (*Print or Type)* ______________________

Signature of Blaster-in-Charge ______________________

Certification Number of Blaster-in-Charge ______________________

Suggested Equipment List*- Electrical Blasting

*(minimum suggested list; not necessarily all inclusive)

Toolbox or Bag
Initiating Device
Spare Batteries for above
Blasting Multimeter or Galvanometer (suggest digital)
Spare Batteries for above
Electrical Tape
Wire Cutters / Insulation Strippers
Powder Punch
Mirror for looking in holes
Knife (stainless steel)
Loading Pole (wood or PVC)
Burden Pole
25 Ft. Tape
Gloves (nitrile coated for dynamite handling)
50 Ft. or 100 Ft. Depth Gauge, Spare Non-Sparking Weights
Compressed Gas Horn for Alarm
Handheld Radios (communications, guards)
500 Ft. of 12 Gauge Duplex Shooting Line
Reel for above
1000 Ft. of 20 Gauge Duplex Connecting Wire
Shot Report Forms
Pen or Pencil
Scale/ Template
Notebook or Paper
Clinometer or Abney Level
Calculator
Spray Paint for marking hole locations, depth, conditions
Paper Stemming Bags For horizontal or inclined holes

EXPLOSIVES

- Correct Quantity and Type of Detonators (length and delay periods)
- Correct Quantity and Type of Boosters, if required
- Correct Quantity and Size of Cartridged or Packaged Explosives (if used)
- Adequate Quantity and Type of Bulk Explosives

Suggested Equipment List*- Non-electric Blasting

*(minimum suggested list; not necessarily all inclusive)

Toolbox or Bag
Initiating Device
Spare Batteries or 209 Shotgun Primers in Original Packaging
Electrical Tape
Wire Cutters / Insulation Strippers
Powder Punch
Mirror for looking in holes
Knife (stainless steel)
Loading Pole (wood or PVC)
Burden Pole
25 Ft. Tape
Gloves (nitrile coated for dynamite handling)
50 Ft. or 100 Ft. Depth Gauge, Spare Non-Sparking Weights
Compressed Gas Horn for alarm
Handheld Radios (communications, guards)
Splice Kit for Shock Tube
Shot Report Forms
Pen or Pencil
Scale / Template
Notebook or Paper
Clinometer or Abney Level
Calculator
Spray Paint for marking hole locations, depth, conditions
Paper Stemming Bags for inclined or horizontal holes

EXPLOSIVES

- Correct Quantity and Type of Detonators (length and delay periods, both downhole and connectors)
- Correct Quantity and Type of Delay Connectors (length, type, and delay periods)
- Correct Quantity and Type of Boosters, if required
- Correct Quantity and Size of Cartridged or Packaged Explosives (if used)
- Adequate Quantity and Type of Bulk Explosives
- 1500 Ft. of Shock Tube for leadline
- Detonator or Delay Connector for leadline

<u>DMM SAFETY TALK:</u> REVIEW OF BLAST SITE ACCIDENT

A certified blaster was seriously injured on August 27, 1998 while loading a shot at a quartzite mineral mine in Frederick County, Virginia. The victim suffered a fractured elbow and wrist, and multiple bruises when he fell off the 38-feet high free face being loaded with explosives.

The contract blaster was in the process of checking burden (10' – 18') on the front line of boreholes when a portion of the free face he was standing on suddenly fell. The DMM investigation of the accident revealed that a tetrahedral shaped boulder 9' X 8' X 8' fell out of the free face causing the sudden fall of ground beneath the victim. It was also noted that water being pumped from wet boreholes was discharged near the slide area, which would have increased the potential for ground/slope failure.

Drillers and blasters can avoid similar accidents by following safe work procedures prescribed in **<u>DMM Safety & Health Regulations</u>**, which include the following:

(1) Examine the free face, drilling/loading bench, and bench or wall above prior to the start of work, and frequently thereafter to ensure safe work conditions (4VAC 25-40460). <u>Never</u> work under or near hazardous walls or benches (4VAC 25-40-430).

(2) When measuring the free face to establish the drill pattern or powder factors, stay a safe distance from the edge of the bench or back-break fractures; if it is necessary to work close to the edge where there is a danger of falling, a safety harness and tied-off line must be used (4VAC 25-40-1740).

(3) Ensure that quarry development ensures ground stability by establishing maximum height of benches based on geologic condition of benches and walls, and the size of equipment being used to load and haul shot rock (4VAC 25-40-390).

(4) Ensure that quarry benches used as haul roads are wide enough to allow for construction of safety berms capable of restraining the largest type of mobile equipment being used, and the safe operation and passage of mobile equipment (4VAC 25-40-410).

(5) Ensure that rim of quarry wall is stripped of overburden and trees for at least ten feet, and that remaining overburden is sloped to the maximum slope or angle at which the material remains stable (4VAC 25-40-400).

The working environments of drillers and blasters can pose hazards from equipment being operated, the manner in which the equipment or explosive material is being used, or the area in which the work is being performed. To avoid accidents, all miners and supervisors must consider the task at hand, and how to accomplish the assigned task without injury to themselves, others, or property/equipment.

BLASTING AND GEOLOGY

By
Robert E. Morgan
Division of Mineral Mining (DMM)
Virginia Department of Mines, Minerals, & Energy

A DMM technical presentation to the Ninth Annual Pennsylvania Drilling & Blasting Conference, November 11-12, 1999 sponsored by the Pennsylvania State University Department of Energy and Geoenvironmental Engineering, the International Society of Explosives Engineers, and the Pennsylvania Department of Environmental Protection.

Drillers and blasters often find themselves working in various types of rock with significantly different geologic characteristics. Geologic conditions may change from mine to mine, or even bench to bench in some rock formations. Failure to adjust drilling and blasting design to be consistent with changes in geology can result in unequal burden on the post blast face, or an increased risk of bench failure while drilling. The risk of an accident or poor shot performance can be significantly reduced by careful examination of geologic conditions of the quarry bench, and making any necessary adjustments to the drill pattern or shot design.

Some of the geologic features which can serve as a clue in identifying conditions which could adversely impact drilling and blasting include the following:

- "Backbreak" (post blast fractures) near the edge of bench
- "Jointing" (fractures) which can disrupt fragmentation
- Limestone "dipping" toward free face of bench which can increase potential for excessive burden ("toe") at floor level of bench.
- Granite "slip" which can increase potential for material sliding from free face during drilling or after detonation of blast
- "Solution cavities" in limestone bench which can result in excessive powder accumulation and subsequent flyrock
- Soft rock over hard rock in bench to be blasted which can result in excessive energy in top portion of borehole
- Water seepage resulting in wet boreholes requiring different type of explosive product
- "Fault zone" (significant fracturing) in a distinct area of quarry which increases potential for unstable ground conditions

Knowledge gained by careful examination of the bench, previous blast reports, and the driller's logbook is critical in developing a safe and effective shot design. A sudden increase in drill penetration rate speaks volumes about the rock behind the free face, which cannot be seen. It is vital that the driller convey this information to the blaster by means of an accurate drill logbook which details depth and condition of each borehole. **The more geologic information available to the blaster, the better the design of the shot.**

Blasters can avoid the mistakes of others that have resulted in unstable free face, bench failure, flyrock or other undesirable effects by careful consideration of geologic conditions; then developing drill patterns and shot designs that utilize the minimum amount of powder required to achieve the desired fragmentation.

HANDLING MISFIRES AT MINERAL MINES
(Blaster training handout)

By definition, misfire means the partial or complete failure of a blast to detonate as planned; and the cause can often be traced back to an error in executing the planned blast. Some of the specific causes include the following:

(1) failure to connect all series or legwires into the electric circuit.

(2) kink or broken connection in shock tubing causing disruption of ignition.

(3) failure to adequately test and charge tubing with initiation gas.

(4) broken connection of wiring or tubing due to person walking over connections.

(5) lightning strike at or near the blast site.

(6) loaded borehole detonating out of sequence

These types of misfires can be eliminated by careful planning and close supervision of loading of shot by the certified blaster in charge at the blast site. If a misfire should occur, some of the following disposal methods may be appropriate depending on the type of detonation system:

(1) do not approach suspected misfire area for at least 15 minutes, regardless of type initiation system.

(2) carefully approach misfire area to check for positive indicators of a misfire; surface lines, etc.

(3) if surface connecting lines or wires are intact , test and re-fire if sufficient burden provided.

(4) if surface or downlines tubing or wiring is not intact, attempt to remove stemming material to re-prime;
if electric detonators are used, do not use a method (blowing out with air) which could create static electricity.

(5) if sufficient burden is not present, add additional burden for protection by use of dumped material or blast mat.

(6) attempt to wash explosive materials from borehole and remove primer.

Misfires must be handled by a certified blaster. The specific methods employed will depend on the type of explosives and detonators used, and the actual blast site conditions. The misfire area must be barricaded and posted with warning signs until the hazard has been removed. Technical representatives of the powder company can provide valuable information and assistance in disposal of misfires. Misfires should be avoided by careful planning of the shot, and close supervision of loading personnel and activities.

GENERAL RULES OF THUMB FOR BLASTING

1. Burden should at least equal 2 times the diameter of borehole in feet; if diameter is 6½ inch burden should be 13 feet.

2. Spacing should at least equal 1½ times burden; if burden is 13 feet, spacing should be 19.5 feet.

3. Primer cartridge length should at least equal half the borehole diameter; if diameter is 6½ inch, cartridge length should be at least 3¼ inch.

4. Stemming length should at least equal burden; if burden is 13 feet, stemming should be at least 13 feet.

5. Powder factors should be based on density and other geologic characteristics of rock to be blasted.

6. Explosives in boreholes should be totally coupled (completely fills borehole diameter); packaged units can be slit and tamped to achieve coupling.

7. Certified blaster should always verify actual distances to inhabited buildings and limits for airblast and ground vibration prior to designing and loading a shot.

Once specific data has been obtained from initial/test shots, the blaster can adjust these conservative values to reflect actual conditions at mine.

GEORGE P. WILLIS
ACTING DIRECTOR

DIVISIONS
ENERGY
GAS AND OIL
MINED LAND RECLAMATION
MINERAL MINING
MINERAL RESOURCES
MINES ADMINISTRATION

COMMONWEALTH OF VIRGINIA

Department of Mines, Minerals and Energy
Division of Mineral Mining
900 Natural Resources Drive, Ste.400
Charlottesville, VA 22903
(434) 951-6310
Conrad T. Spangler III, Division Director

MEMORANDUM

TO: All Licensed Mine Operators and Blasting Contractors

FROM: ____
Conrad T. Spangler, Division Director

SUBJECT: Flyrock Prevention

DATE: September 28, 2006

The mineral mine community in Virginia has experienced a number of flyrock incidents in the recent past. More specifically, there have been 5 reported incidents since December 2003; 4 of them have occurred since March 2005.

This is a matter of grave concern to the Division. All of these incidents had the potential to cause death or serious personal injury to citizens.

All operators and blasting contractors in the Commonwealth of Virginia are urged to review their policies and blasting procedures to assist in the elimination of this problem.

Furthermore, the Division strongly recommends that all operators and blasting contractors provide additional training in flyrock prevention to their certified blasters.

The occurrence of flyrock can be considered an "imminent danger", and result in the issuance of a Closure Order to the operator. All incidents of flyrock should be reported to the Division of Mineral Mining by the quickest available means.

The Division stands ready to provide assistance to all operators and blasting contractors, including training, training materials, and on-site assistance.

If you have any questions or requests for assistance, you may contact your mine inspector, Tom Bibb, or me at (434) 951-6310.

Enclosure

DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL MINING

LAWS AND REGULATIONS APPLICABLE TO THE PREVENTION OF FLYROCK

REFERENCE:

Mineral Mine Safety Laws of Virginia 2003 Edition

A. Section 45.1-161.292:2. Definitions

"Imminent Danger" – means the existence of any condition or practice in a mine which could reasonably be expected to cause death or serious personal injury before such condition or practice can be abated.

B. Section 45.1-161.292:64. Closure Order

A. The Director or a mine inspector shall issue a closure order requiring any mine or section thereof cleared of all persons, or equipment removed from use, and refusing further entry into the mine of all persons except those necessary to correct or eliminate a hazardous condition, when (i) a violation of this chapter and Chapters 14.5 (§ 45.1-161.293 et seq.) and 14.6 (§ 45.1-161.304 et seq.) has occurred, which creates an imminent danger to the life or health of persons in the mine; (ii) a mine fire, mine explosion, or other serious accident has occurred at the mine, as may be necessary to preserve the scene of such accident during the investigation of the accident; (iii) a mine is operating without a license, as provided by § 45.1-161.292:30; or (iv) an operator to whom a notice of violation was issued has failed to abate the violation cited therein within the time period provided in such notice for its abatement; however, a closure order shall not be issued for failure to abate a violation during the pendency of an administrative appeal of the issuance of the notice of violation as provided in subsection D of § 45.1-161.292:63. In addition, a technical specialist may issue a closure order upon discovering a violation creating an imminent danger.

Virginia Safety and Health Regulations for Mineral Mining 2004 Edition

I. 4 VAC 25-40-10 Definitions

"Flyrock"- means any uncontrolled material generated by the effect of a blast that was hazardous to persons, or to property not owned or controlled by the operator.

II. 4 VAC 25-40-800 Use of Explosives

D. The design and loading of a blast shall provide sufficient burden, spacing, and stemming to prevent flyrock and other dangerous effects.

FLYROCK HAZARD ALERT

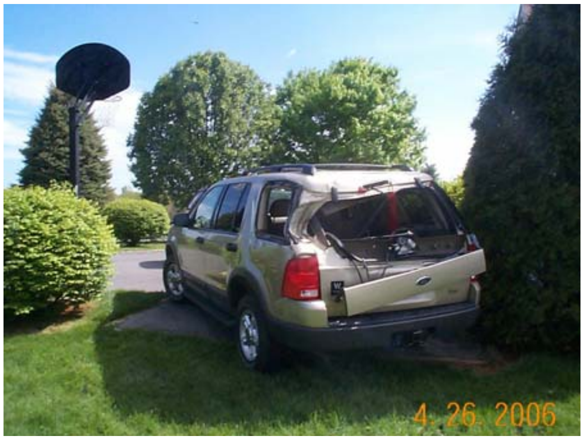
"Flyrock" means any uncontrolled material (usually rock) that is thrown by a blast and is hazardous to persons, or to property not owned or controlled by the mine operator. Flyrock can travel 3,000 feet or more, reach speeds of 400 miles per hour, and can penetrate buildings, smash vehicles, and cause great bodily harm.

From December 2003 through August 2006, 5 serious flyrock incidents have occurred from blasting at surface mineral mines/quarries in Virginia. All of these incidents had the potential for very serious or fatal results. Fortunately, no one was injured, though significant damage to property (vehicles and structures) did occur in each of these incidents.

CAUSES OF FLYROCK

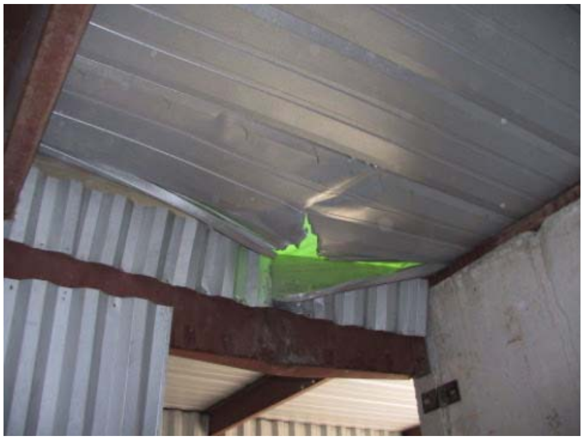
Investigations have found that flyrock is often the result of:

- Blast holes with insufficient stemming
- Blast holes with excessive burden
- Blast holes with insufficient burden
- Secondary blasting with insufficient burden (toe holes, boulders)
- Weaknesses in the rock structure (mud seams, faults, cavities, fractures, etc.)
- Excessive energy due to high powder factors
- Insufficient energy due to low powder factors



BEST PRACTICES

Blasters can minimize the risk of flyrock by careful planning and by utilizing the following practices:



- Adjusting the drill pattern and/or hole depths for geology, face geometry, and shot surface topography
- Examining the drill log and blast site geology, and making appropriate adjustments when loading
- Accurately measuring burden on the free face and succeeding rows
- Adjusting the explosive charge in the blast hole for the actual burden
- Adjusting the stemming depth and/or decking to maintain adequate burden on all sections of the blast hole
- Adjusting timing to ensure adequate time for rock movement
- Using extraordinary caution when shooting boulders or toe holes with small burdens

Blasters now have a wide variety of initiation devices and explosive products that allow for safe, effective blasting. The certified blaster has the responsibility to use those products safely. He must carefully evaluate the conditions, design the shot, supervise the loading, and ensure the safety of miners and the public during detonation.

<u>PREVENT FLYROCK – THINK BEFORE YOU LOAD</u>

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Surface Blaster Certification Study Guide. Big Stone Gap, Virginia: Department of Mines, Minerals, and Energy. Division of Mines, 1994.

For information on assessing structural damage please refer to Blasting Damage and Other Structural Cracking.*

*Blasting Damage and Other Structural Cracking (A Guide for Adjusters and Engineers) American Insurance Services Group, Inc.; Property Claim Services, Third Edition 1990.